AN EXAMINATION OF THE MECHANISMS OF INCUBATION

A Thesis

by

NICHOLAS WILLIAM KOHN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2005

Major Subject: Psychology

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Approved by:

Chair of Committee,	Steven M. Smith
Committee Members,	Stephanie Knight
	Takashi Yamauchi
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ABSTRACT

An Examination of the Mechanisms of Incubation.

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Nicholas William Kohn, B.A., The University of Michigan

Chair of Advisory Committee: Dr. Steven Smith

Several hypotheses have been offered to explain the mechanisms involved in incubation, the phenomenon in which resolution of a problem benefits more from interruption than continuous solution attempts. The predictions of three hypotheses were tested by varying the level of attention demanded by an incubation task. It was found that a task that requires a moderate amount of attention leads to the greatest resolution of the problem during distraction and incubation intervals. This result supports the Withdrawal of Attention hypothesis of incubation and is inconsistent with the predictions of the Incremental Work and Forgetting Fixation hypotheses.

DEDICATION

This thesis is dedicated to my parents, Harold Kohn and Barbara Gold. They have always stressed the importance of education in one's life. Without their guidance and support, I surely would not have come this far.

ACKNOWLEDGMENTS

I would like to acknowledge the following people for helping me complete my master's thesis: Eliaz Segal for suggesting the Withdrawal of Attention Hypothesis; my undergraduate assistants, Julie Brown, Shawn Ferreiro, and Kim Crenshaw for assisting with running experiments and coding data; and my committee members Steve Smith, Takashi Yamauchi, and Stephanie Knight for their guidance throughout this project.

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INTRODUCTION

"Put the problem aside and come back to it." This is a phrase many people have heard at least once. This refers to the psychological phenomenon known as "incubation." Incubation is a term popularized in the 1920's to refer to laying aside a problem as a step towards solution (Wallas, 1926; Woodworth & Schlosberg, 1954). Incubation can be observed in a real-world setting for problem solving (e.g, returning to a skipped problem on a school exam), retrieving a memory (e.g., remembering the capital of Australia), and in creativity (e.g., Kary Mullis thinking of the Nobel prize winning idea of a polymerase chain reaction while driving home from work). By its very nature, the concept of incubation is counter-intuitive. If a person wants to succeed in solving a problem, retrieve a memory, or be creative, they should continuously work towards achieving their goal.

Despite its prevalence in the real world, incubation is not easily observable in an experimental setting. Early research struggled to find evidence for incubation effects. Gall and Mendelsohn (1967) examined the effect of incubation, free-association training, and continuous work on solving problems. They found in all instances that continuous work was as good or better than an incubation period. Dominowski and Jenrick (1972) also found that an incubation period could be detrimental to problem resolution; however their result is dependent upon the person's cognitive ability. Other research simply found no effects of incubation intervals and concluded that incubation may not

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This thesis follows the style of *Journal of Applied Psychology*.

exist (Olton, 1979; Olton & Johnson, 1976). In the early stages of incubation research, few experiments were able to provide supportive evidence for incubation (C. Patrick, 1938; Silveira, 1971). With time, improved laboratory techniques allowed for replicable findings of incubation effects. Studies finding incubation effects have been able to do so using such problems such as rebuses, anagrams, and Remote Associate Test problems (Goldman *et al.*, 1992; Smith & Blankenship, 1989, 1991; Smith & Vela, 1991). While these studies are effective in demonstrating the robustness of incubation effects, there is an existing debate as to the mechanisms of incubation that allow for the benefit to occur. Hypotheses such as the Fatigue hypothesis (Woodworth & Schlosberg, 1954), Incremental Work hypothesis (Bowers *et al.*, 1990; Browne & Cruse, 1988; Weisberg & Alba, 1981; Yaniv & Meyer, 1987), and the Forgetting Fixation hypothesis (Smith & Blankenship, 1989, 1991) have been offered to explain mechanisms of incubation.

The Fatigue hypothesis is the idea that a person becomes mentally exhausted during attempts to solve a problem (Woodworth & Schlosberg, 1954). An incubation interval provides a period in which the person can recover from fatigue. When the person returns to the problem, they are mentally “fresh” and can resolve the problem. Recent studies have provided evidence that the Fatigue hypothesis may not be a correct explanation of incubation effects. Incubation effects were shown to occur even when a participant is occupied by a demanding task (Goldman et al., 1992; Smith & Blankenship, 1991). It is possible that in some cases fatigue is sufficient for incubation effects to occur, it is clear that it is not necessary.

The Incremental Work hypothesis states that during incubation, the mind is at work putting together "pieces" towards a solution. This hypothesis has two variants: the Conscious Work hypothesis and the Unconscious Work hypothesis. According to the Conscious Work hypothesis, a person is consciously engaged in solving the problem despite not having the problem physically in front of them (Browne & Cruse, 1988; Gall & Mendelsohn, 1967; Weisberg & Alba, 1981). During incubation intervals, people encounter information that acts as hints towards solution. Thus, the Conscious Work hypothesis states that there is nothing special about incubation intervals, and that resolution can be attributable to continuous work on the problem. This explanation of the mechanisms of incubation is contrasted by the numerous studies that have shown problem resolution while using incubation intervals containing tasks that would make continuous, conscious work extremely difficult (A. S. Patrick, 1986; Peterson, 1974; Smith & Blankenship, 1991; Smith & Vela, 1991).

The Unconscious Work hypothesis also states a person is engaged in incremental work towards solution; however, this work is being performed without the person being aware of it. Yaniv and Meyer (1987) offer an explanation for incubation effects in which initial attempts at solving the problem sensitize relevant information stored in long-term memory. While this information may be temporarily inaccessible, a slow spreading activation occurs during incubation. As the length of the period increases, the probability of resolution increases as memory traces are strengthened past threshold and trigger integration with other relevant problem information. Problem resolution can be enhanced by chance encounter with stimuli during incubation that provides useful clues

(Bowers et al., 1990; Yaniv & Meyer, 1987). Both versions of the Incremental Work hypothesis carry the assumption that solution occurs when the mind is able to work towards solution, either consciously or by unconscious spreading activation.

The Forgetting Fixation hypothesis revolves around the idea that in order for incubation effects to occur, a person has to have a mental fixation removed (Smith & Blankenship, 1989). According to the theory, the correct concept in memory is in competition for retrieval with other concepts. This is because more than one concept is associated with the problem. Fixation occurs when one of these competing associates ("blocker") becomes strongly activated and reaches conscious threshold. The more a person thinks of this blocker, the stronger the association between the problem and the blocker becomes. Only when fixation on this blocker dissipates can the correct concept be activated to the point it reaches conscious threshold. This theory predicts that the better an incubation task is at causing the person to forget the fixation, the more likely resolution will occur. Evidence for the Forgetting Fixation hypothesis has emerged from investigations of fixation. Silveira (1971) found that incubation effects were greater when an incubation interval occurs later in the solution attempt rather than early in the solution process. Another study observed incubation effects only when fixation was induced (Smith & Blankenship, 1991). There are two versions of the Forgetting Fixation hypothesis. The first states that fixation on the blockers weaken in strength with time due to memory decay (Woodworth & Schlosberg, 1954). Smith and Blankenship (1989) found that incubation resolution rates increases at approximately the same rate as memory for a blocking clue decreased. Once the desired concept has surpassed the blocker in strength, the solution can then be retrieved (Smith, 1995). The second version of the hypothesis states that a change in the problem context can weaken the strength of the blocker. This stems from the Stimulus Sample Theory (Estes, 1955; Glenberg, 1979) that forgetting is the result of differently encoding a stimulus at learning than from the encoding at test. If the problem context is changed during incubation, then the blocker will be forgotten. Silveira's (1971) result lends support for the ideas that incubation intervals serve as an opportunity for a context change after a person has become fixated on an incorrect solution during their initial attempt.

There has been enough evidence produced through the years that one cannot discount the Incremental Work hypothesis or the Forgetting Fixation hypothesis. Perhaps the reason that both hypotheses have been supported by various studies is that elements of both hypotheses are correct. The Incremental Work hypothesis states that incubation effects occur when a person's mind is at ease, allowing (conscious or unconscious) incremental-like work that leads to solution. The Forgetting Fixation hypothesis states that incubation effects occur when a person's mind is occupied by other demanding tasks that weaken the strength of the fixation or change the context of the problem. A combination of elements from these two hypotheses leads to forming a new hypothesis, the Withdrawal of Attention hypothesis[1]. This hypothesis states that incubation effects are the strongest when there is an incubation task that removes enough attention from the problem to remove fixation on the incorrect concept, but is not so demanding that incremental-like work can be (consciously or unconsciously) performed.

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[1] The Withdrawal of Attention hypothesis was originally suggested by Eliaz Segal.

This explanation of incubation effects makes sense because of the following two reasons. First, the fact that fixation has been shown to be problematic in solving numerous insight problems (Jansson & Smith, 1991; Luchins & Luchins, 1959; Smith & Blankenship, 1989, 1991; Wiley, 1998) is evidence that fixation should be removed during incubation. Secondly, an incubation task that employs all of a person's cognitive resources would not allow any work to be done towards resolving the problem. Therefore, an incubation interval would be of greatest benefit for resolution when it contains a task that withdraws a moderate amount of attention away from the problem.

Past studies have examined the effects of varied incubation tasks on problem resolution. Smith and Blankenship (1989) performed a series of experiments on the effectiveness of incubation intervals for resolving problems. While incubation effects were observed, there were no differences in resolution rates for the three experimental incubation tasks: arithmetic problems, story reading, and music perception tasks. The lack of differences between these three types of incubation tasks does not support nor disprove the Withdrawal of Attention hypothesis because it was not known how much attention each task demanded. Smith and Vela (1991) examined the effects of incubation intervals on reminiscence, the recalling of information on a subsequent test that was not recalled on the first test. They did find greater reminiscence following an incubation interval containing maze problems compared to an interval where the participant sat quietly. This result supports the Forgetting Fixation hypothesis, but offers no clues for the Withdrawal of Attention hypothesis because only two levels of attention demands were tested. Olton and Johnson (1976) performed a more thorough examination, testing various types of incubation tasks such as Stroop tests, relaxing environments, viewing visual analogies of the problem's solution, and actively reviewing the problem. However, a flawed design led to Olton and Johnson finding no incubation effects and no difference between the types of incubation tasks. What is needed is a series of experiments that can produce incubation effects while systematically manipulating the attentional demands of an incubation task.

The present study tested the predictions of these three hypotheses by using Remote Associate Test (RAT) problems to observe incubation effects. RAT problems were originally designed as measures of creativity (Mednick, 1962). This divergent thinking task requires participants to think of one word that they can use to form expressions with all three words of the problem. For example, the word "Pit" would be used to solve the RAT problem: ARM COAL STOP. While RAT problems are no longer used as measures of creativity, they have been successfully used in incubation studies (Jung-Beeman *et al*., 2004; A. S. Patrick, 1986; Smith & Blankenship, 1991).

In order to readily observe incubation effects in the present experiments, fixation on incorrect solutions was induced. Past research has suggested that in order to readily observe incubation effects in an experimental setting, one must make the problems more difficult by inducing fixation (Silveira, 1971; Smith & Blankenship, 1989). Incubation was induced by preceding each RAT problem with another verbal task, which contained a cue. Sometimes this cue was the solution to that trial's RAT problem while other times this cue was misleading. Encounters with trials that contained helpful cues likely led participants to develop a strategy in which they would use a word from this task in their initial attempt to solve that trial's RAT problem. By using this strategy, participants were likely to become fixated on an incorrect solution in trials where the cue is misleading. The present study is the first experiment known to use a trial-by-trial paradigm for studying incubation effects. Previous studies that employed multiple incubation problems did so by giving participants a first attempt on all problems, followed by an incubation interval, and then a second attempt on all problems (Peterson, 1974; Smith & Blankenship, 1989, 1991). In the present study, each trial consisted of Two-Word Phrase Task (contains the cue), an initial attempt on the RAT problem, an incubation interval, followed by a second attempt on the RAT problem (see Appendix A). Thus, each trial was disjoint and the cause of any incubation effects would be attributable to only events occurring within that trial.

The goal of the present experiments was to examine incubation effects while manipulating the incubation interval. During each interval, a Digit Monitoring Task was given to each participant in which they were required to count occurrences of a pattern of numbers while digits flashed on a screen. The varied complexity of these number patterns was designed to have the effect of varied levels of attention demands: low, medium, and high. The other variable of interest in the present study was the nature of the task during the incubation interval. The first two experiments used distraction intervals in which a participant's attention was divided by the dual presence of the digits and the RAT problem on the screen. Experiments 3 and 4 used incubation intervals in which digits flashed on the screen, but the RAT problem was removed. In daily life, there are occurrences of resolving a work-related problem while being distracted and after an incubation period. Thus, it was of interest to study both types of intervals to examine if there are differences in resolution performance and underlying mechanisms.

By manipulating the difficulty of the Digit Monitoring Task, the present set of experiments was able to test the predictions of the three main incubation hypotheses. These three hypotheses differences lie in their view of the mechanisms. However, it is possible to contrast these hypotheses by their predictions regarding incubation tasks. The Incremental Work hypothesis states that resolution is optimal when a person is able to (consciously or unconsciously) work towards solution without interference. Therefore, the less demanding an incubation task is, the better the resolution. The Forgetting Fixation hypothesis states the opposite. Resolution is optimal when an incubation task is so demanding, that it causes the person to forget about the fixated concept. The one assumption is that greater levels of distraction result in greater forgetting of the fixated concept. The Withdrawal of Attention's hypothesis states that resolution is best achieved when an incubation task is requires enough attention to forget about the fixated concept, but allows the person to work towards solution. The assumption here is that a moderate amount of attention causes removal of the fixation as well as incremental-like work. Thus, these three hypotheses make clear predictions regarding the level of attention demanded by the incubation task (see Appendix B). If resolution is greatest for a task requiring a low level of attention, then there is support for the Incremental Work hypothesis; greatest resolution for a medium level is support for the Withdrawal of Attention hypothesis; and greatest resolution for a high level is support for the Forgetting Fixation hypothesis.

Examining these hypotheses' predictions was done by analyzing resolution scores and error rates for the Digit Monitoring Task. Calculating resolution scores (proportion of initially unsolved RAT problems that were resolved during incubation) was an indicator of which attention level (low, medium, or high) was optimal for problem resolution. Digit monitoring error rates (proportion of trials in which the participant miscounted the number of digit patterns) was analyzed separately for when participants solved the RAT problem initially and for when participants resolved the problem during the interval. This analysis was an indicator of how distracting was the incubation task and how much the participant focused on the RAT problem. Together, the resolution rates and the digit monitoring error rate provided clues as to the mechanisms involved in distraction and incubation intervals.

EXPERIMENT 1

In Experiment 1, participants saw a series of trials. On each trial, participants were given a Two-Word Phrase Task, an initial attempt on a RAT problem, followed by an incubation period during which time they monitored for digit patterns. Each trial concluded with a second attempt on the RAT problem. On Blocking trials, initial fixation was induced on the RAT problem. This was conducted by presenting an incorrect solution to RAT via a Two-Word Phrase Task immediately preceding the RAT problem. Levels of attention demands during the incubation period were manipulated. In addition to the three levels of attention, two comparison conditions were tested. One of these examined the case where there was no incubation interval (test followed by an immediate retest). The other comparison condition served as a control to the attention levels, where digit monitoring occurred, but participants were not required to monitor for digit patterns. While the three hypotheses only make predictions regarding the manipulation of attention levels, these two comparison conditions provided clues as to the general picture of distraction and incubation intervals. Incubation effects were measured by calculating the percentage of RAT problems not solved initially, but that were later resolved following the incubation period. In Experiment 1, the incubation task consisted of monitoring for digit patterns while the RAT problem was concurrently displayed. An incubation problem involves removing the fixated problem for a certain period of time. In Experiment 1 the problem was never removed. Thus, Experiment 1 is better termed a “distraction” experiment. The purpose of Experiment 1 was to test the predictions of the three hypotheses of the underlying mechanisms of incubation (see

Appendix B). The Incremental Work hypothesis predicts that an incubation task requiring a low amount of attention will have the highest incubation resolution. The Withdrawal of Attention hypothesis predicts an incubation task requiring a medium amount of attention will have the greatest incubation resolution, whereas the Forgetting Fixation hypothesis predicts that a task demanding a high amount of attention will be optimal.

Method

Participants

Participants for this study came from an introductory psychology course and received credit towards course completion. These students had the option of signing up for the present experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 113 students participated in this experiment and were randomly selected into one of the five conditions: low, medium, high, control, and no incubation.

Materials

Three types of tasks were given to participants: a Two-Word Phrase Task, a RAT problem, and a Digit Monitoring Task. The RAT is a word association task that contains three words. These RAT problems were compiled from prior studies (Smith *et al.*, 1993) or by experimenter-generation.

The Two-Word Phrase Tasks also contain three words each and were constructed from either the words used in the corresponding RAT (see Table 1) or from experimenter generation. In the Two-Word Phrase Task, participants were presented with three words (e.g., FLAG VAULT POLE) on the screen and asked to form two compound words or 2 two-word phrases using only those three words provided. For example, you could form “FLAG POLE” and “POLE VAULT” from the displayed words.

The RAT differs in that participants were asked to come up with a word not displayed on the monitor that can be used to make a compound word or two-word phrase with ALL three of the words (e.g., ARM COAL STOP) on the screen. For example, the solution “Pit” makes the common word or phrase, ARMPIT, COAL PIT, and PITSTOP.

The Digit Monitoring Task contained a list of 40 odd digits ranging in value from 1-9. Each list contained random numbers along with strings of two odds in-a-row, three odds in-a-row, or five odds in-a-row (dependent upon condition). For this experiment, a total of 84 lists were created. The entire experiment was presented via Microsoft PowerPoint 2000 on a 20” computer monitor. For the experiment, a different PowerPoint presentation was used for each condition.

Design and Procedure

In the three experimental conditions (Low, Medium, and High) and the Control condition, each trial contained a Two Word Phrase Task, a RAT problem, and a Digit Monitoring Task, presented in this order (see Appendix A). In the Control condition, participants were only told to watch the digits closely. Therefore, they were not asked to answer the number of pattern occurrences. The No Incubation condition contained only Two-Word Phrase Tasks and RAT problems.

In all conditions, participants were given 20 seconds to complete the Two-Word Phrase Task and 15 seconds for the initial RAT attempt. In the Digit Monitoring Task, participants were asked to monitor for strings of certain length of odd digits. Participants in the Low condition counted the number of occurrences of two odds in-a-row; participants in the Medium condition counted the number of occurrences of three odds in-a-row; and participants in the High condition counted the number of occurrences of five odds in-a-row. Digits flashed on the screen at a rate of one per second for a total duration of 40 seconds. Concurrently, the RAT was continuously displayed below the digits so that participants could continue to work on solving the RAT while they monitored the digits. Thus, this incubation period was more of a distraction period, with the digit monitoring distracting active work on the RAT. At the end of this period, participants were given 7 seconds to write down the number of occurrences they monitored and the answer to the RAT if they solved it during the digit presentation (measure of incubation effect). Participants in the No Incubation condition were given 20 seconds for the Two-Word Phrase Task, 15 seconds of the initial RAT presentation, 1-second pause of blank screen, and 7 seconds of a second RAT presentation (measure of incubation effect).

Twenty-eight trials were constructed for this experiment. Of these, 12 were classified as “Blocking”, six as “Helpful” and six as “Unrelated.” These trials differ by the words used in the Two-Word Phrase Task (see Table 1). The Blocking trials contained a “blocker” word in the Two-Word Phrase Task that would be associated with only two of the three words of that trial’s RAT. The goal was for participants to become fixated on the incorrect solution word (blocker). For example, after completing a Two-Word Phrase Task (e.g., CAT BOARD BLACK; solution: “Blackboard, Black cat”), the participant is likely to be fixated on the blocker word “Black” when completing the subsequent RAT problem (e.g., CAT SLEEP BOARD; solution: “Walk”). The Helpful trials contained the solution to the RAT in the corresponding Two-Word Phrase Task. For example, a Two-Word Phrase Task of: STAR MOVIE DUST, will prime the solution to the subsequent RAT problem (FALLING MOVIE DUST), “Star.” The purpose of using Helpful trials was for participants to gain experience in using words from the Two-Word Phrase Task in solving the RAT, thus increasing the likelihood of fixation in the Blocking trials. The Unrelated trials contain words in the Two-Word Phrase Task that are completely unrelated to the corresponding RAT. The purpose of using Unrelated trials was to reduce the ease in which participants can distinguish between Helpful trials and Blocking trials. The remaining four trials were used as examples (one Blocking, one Helpful, and two Unrelated) to aid in participants’ procedural knowledge of the experimental tasks.

Table 1

Sample Test Stimuli

Example of a Helpful Trial

Test	Stimuli			Answers
Two-Word Phrase Task:	Star	Movie	Dust	Movie Star, Star Dust
Remote Associate Test:	Falling	Movie	Dust	Star

Example of an Unrelated Trial

Test	Stimuli			Answers
Two-Word Phrase Task:	Hop	Door	Bell	Door hop, Doorbell
Remote Associate Test:	Goat	Pass	Range	Mountain

Example of a Blocking Trial

Test	Stimuli			Answers
Two-Word Phrase Task:	Cat	Board	Black	Blackboard, Black Cat
Remote Associate Test:	Cat	Sleep	Board	Walk

Results

Blocking Trials

A significance level of $p < .05$ was used on all statistical tests for all experiments reported, unless otherwise specified. A one-way Analysis of Variance (ANOVA) analyzed the effects of level of distraction (no incubation, control, low, medium, high), a between-subjects variable, using the proportions of RAT problems solved initially as the dependent variable (see Table 2). No main effect of distraction level was found [$F(4,108) = 1.35$, $MSE = .01$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution (proportion initially unsolved RAT problems that were resolved in/following incubation) as the dependent variable (see Table 2). A main effect of distraction level was found [$F(4,108) = 4.45$, $MSE = .01$]. Pairwise LSD tests revealed that the medium condition yielded significantly higher incubation resolution rates than did the low and the high conditions (see Figure 1). The control condition also yielded significantly higher incubation resolution rates than did the low and high conditions. The no incubation condition had a significantly greater incubation resolution rate than did the high condition.

Table 2

Exp.1: Solution Rates for RAT Problems in Blocking Trials

Distraction level	Proportion Solved Initially (*SE*)	Incubation Resolution (*SE*)
No incubation	.26 (.02)	.08 (.02)
Control	.29 (.02)	.13 (.02)
Low	.27 (.03)	.04 (.02)
Medium	.28 (.03)	.11 (.02)
High	.33 (.03)	.02 (.02)

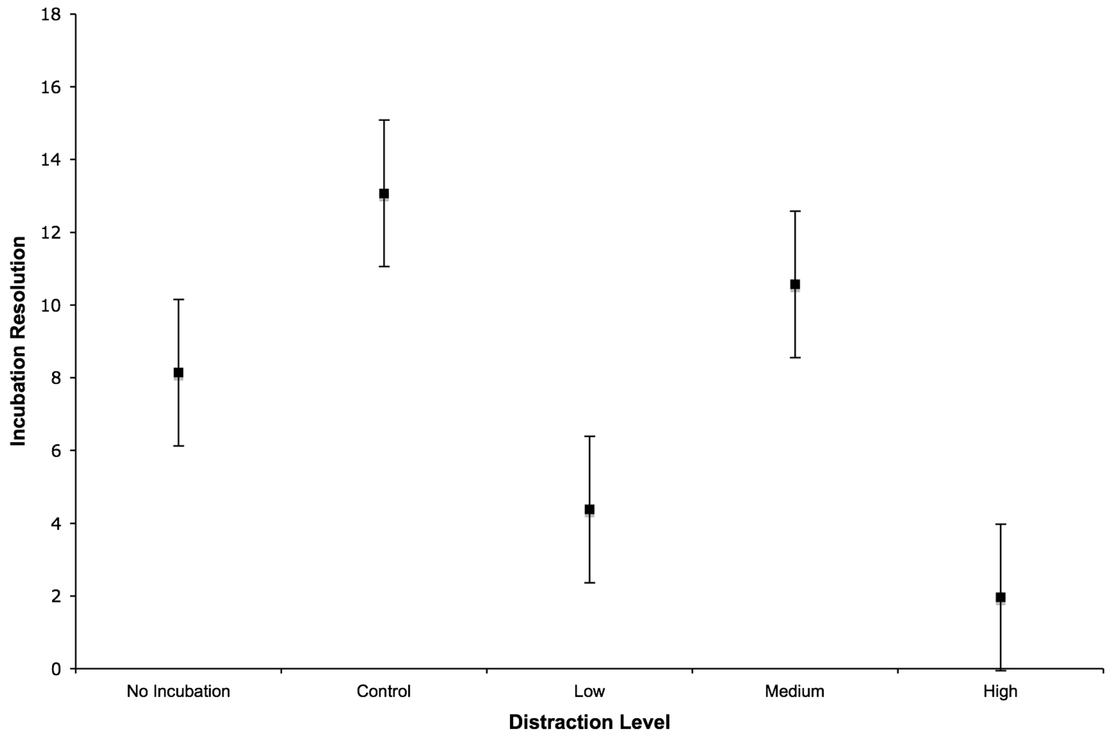


Figure 1. Experiment 1: Resolution of Blocking Trials

A one-way ANOVA analyzed the effects of level of distraction using the number of blockers incorrectly given for an answer as the dependent variable. No main effect of distraction level was found [$F(4,108) = 0.88$, $MSE = 1.87$]. The no incubation (M = 1.37, SE = .26), control (M = 0.96, SE = .29), low (M = 1.24, SE = .30), medium (M = 1.38, SE = .30) and high (M = 1.71, SE = .30) conditions answered the RAT problems with a blocker on approximately 11% of the blocking trials.

A manipulation check was run to examine if the experimentally manipulated distraction levels indeed caused different amounts of distraction. A one-way ANOVA analyzed the effects of level of distraction using the error rate (proportion of incorrect

Digit Monitoring Task counts) as the dependent variable[2]. The proportion of trials resulting in a digit monitoring error did not show an increase of errors occurring with more attention demands. In fact, this was slightly reversed with the low (M = .25, SE = .04), medium (M = .21, SE = .04), and high (M = .17, SE = .04) conditions. However, no main effect of distraction level was found [$F(2,60) = 1.14$, $MSE = 0.04$]. A conditional Digit Monitoring Task performance analysis can be found in Table 3. This table displays the proportion of trials resulting in a digit monitoring error given the result of the trial's RAT problem (i.e., initially solved, never solved, resolved in incubation). This table shows that the rate of committing a monitoring error increased from focusing solely on the Digit Monitoring Task (Initially solved) to a second attempt at solution (No resolution) to actually resolving the RAT problem during the distraction interval (Incubation resolution).

Table 3

Exp.1: Error Rates on Digit Monitoring Task for Blocking Trials

Distraction level	RAT problem status		
	Initially solved	No resolution	Incubation resolution
Low	0.15	0.29	0.36
Medium	0.09	0.25	0.43
High	0.15	0.19	0.33

[2] ANOVA's on Error Rate for Unrelated and Helpful trials were also performed, both yielding no main effect of distraction level.

Unrelated Trials

A one-way ANOVA analyzed the effects of level of distraction, using the proportions of RAT problems solved initially as the dependent variable (see Table 4). No main effect of distraction level was found [$F(4,108) = 0.65$, $MSE = .05$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution as the dependent variable (see Table 4). No main effect of distraction level was found [$F(4,107) = 1.11$, $MSE = .04$].

Table 4

Exp.1: Solution Rates for RAT Problems in Unrelated Trials

Distraction level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
No incubation	.33 (.04)	.09 (.04)
Control	.38 (.05)	.18 (.04)
Low	.43 (.05)	.12 (.04)
Medium	.37 (.05)	.12 (.04)
High	.38 (.05)	.07 (.04)

Helpful Trials

A one-way ANOVA analyzed the effects of level of distraction, using the proportions of RAT problems solved initially as the dependent variable (see Table 5). No main effect of distraction level was found [$F(4,108) = 1.91$, $MSE = .06$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution as the dependent variable. No main effect of distraction level was found [$F(4,101) = 1.75$, $MSE = .07$].

Table 5

Exp.1: Solution Rates for RAT Problems in Helpful Trials

Distraction level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
No incubation	.52 (.05)	.26 (.05)
Control	.49 (.05)	.25 (.06)
Low	.60 (.05)	.14 (.06)
Medium	.60 (.05)	.17 (.06)
High	.67 (.05)	.07 (.07)

Discussion

In Experiment 1, incubation resolution was measured while manipulating the level of distraction during the distraction period. Among the three levels of digit monitoring, it was found that the medium condition yielded higher resolution rates than did the low and high conditions. This result lends evidence to the Withdrawal of Attention hypothesis, that a moderate amount of attention yields the greatest incubation. It appears that an incubation effect occurred with the medium condition yielding greater resolution than the no incubation condition, although the difference was not significant. It would however be presumptuous to label this as an incubation effect because participants in the no incubation condition viewed the RAT problem for a shorter amount of time, and this is not a true incubation experiment because the problems were present during the interval. Of all the conditions, the control did yield the greatest incubation resolution. In this condition, participants were given the instructions to watch the digits on the screen, but were not instructed to count any digit patterns. It is difficult to interpret this result because it is not known if participants were watching the digits or were engaged in a different activity (e.g., concentrating solely on the RAT problem).

The present experiment manipulated levels of distraction. This was achieved by varying the complexity of the digit patterns. Theoretically, it should be more difficult to monitor for patterns of five odd digits in-a-row than patterns of two odd digits in-a-row. However, there were no differences in the number of digit monitoring errors among the three levels, even for trials in which RAT problems were initially solved (see Table 3). Interestingly, the incubation resolution pattern was mirrored by the digit monitoring error rates. In the three distraction levels (low, medium, high) the rate of committing a digit monitoring error increased from initially solving the RAT problem to resolving the RAT problem during the distraction period. It is likely that resolving a RAT problem led to the participant momentarily losing track of the digits flashing on the screen, resulting in a digit monitoring error.

It is possible that the proportion of RAT problems initially solved moderated the effect of distraction on incubation resolution. Resolution rates are in part determined by the number of RAT problems not solved initially, which is the pool of problems that can be successfully resolved during incubation/distraction. Furthermore, proportion solved initially is an indicator of the participant's ability, a trait that some research has linked to incubation activity (Davidson, 1995; Dominowski & Jenrick, 1972; Murray & Denny, 1969; Smith & Blankenship, 1991). In Experiment 1, there was no difference between the distraction levels in the proportion of RAT problems solved initially. Therefore, it is safe to assume that the resolution results are due to the distraction levels and not some other factor.

The Helpful and Unrelated trials were analyzed separately because they do not contain blocking clues and are thus different types of problems. No effect of distraction level was observed in either trial type for incubation resolution. In Helpful trials, there is the general trend that increased distraction (control → low → medium → high) led to increased resolution rates. This is intuitive because in Helpful trials, participants did not encounter a blocker and simply needed more time and resources to complete the RAT problem. Across all three trial types, there was the result of the high condition yielding the lowest resolution scores. This can simply be explained by the idea that the more distracted one is, the lower the performance.

Experiment 1 has provided supporting evidence for the Withdrawal of Attention hypothesis. A problem that leads to an impasse is best resolved when a moderate amount of attention is withdrawn. This is because a participant needs a certain amount of distraction to forget about a blocking concept and at the same time needs a certain amount of cognitive resources to activate the correct/desired concept. This result contradicts earlier studies that support the Incremental Work hypothesis (Bowers *et al.*, 1990; Yaniv & Meyer, 1987) and the Forgetting Fixation hypothesis (Smith, 1995; Smith & Blankenship, 1989, 1991).

EXPERIMENT 2

Experiment 2 further investigated the role of attention withdrawal during distraction experiments. In Experiment 1, the greatest amount of resolution occurred in the control condition, where participants were instructed to watch digits, but not asked to monitor for any patterns. It is not known if this was due to a moderate distraction provided by this task (supportive of the Withdrawal of Attention hypothesis), or to participants ignoring the instruction and continuously working towards solution on the RAT problem. To examine this question, in Experiment 2 a condition was tested in which participants were given continuous attempts at solving the RAT problem. Thus, this continuous work condition was akin to the control condition in Experiment 1, with the exception that no distracting digits appeared on the screen during the second RAT attempt. In addition to testing the continuous work condition, three levels of attention demands were tested by manipulating the Digit Monitoring Task. The other purpose of Experiment 2 was to replicate Experiment 1. Experiment 1 was the first known experiment to show that withdrawing a moderate amount of attention during incubation is optimal for resolution. Therefore, a replication was deemed necessary.

Method

Participants

Participants for this study came from an introductory psychology course and received credit towards course completion. These students were given the option of signing up for this experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 100 students participated in this experiment and were randomly selected into one of the four conditions: low, medium, high, and continuous work.

Materials

The same materials from Experiment 1 were used in Experiment 2.

Design and Procedure

The same procedure from Experiment 1 was used in Experiment 2.

In the continuous work condition, there was no Digit Monitoring Task. In its place on each trial was a blank screen that lasted for one second. Following this one-second pause, participants were given a second attempt at the RAT for 47 seconds.

Results

Blocking Trials

A one-way ANOVA analyzed the effects of level of distraction (continuous work, low, medium, high), a between-subjects variable, using the proportions of RAT problems solved initially as the dependent variable (see Table 6). No main effect of distraction level was found [$F(3,96) = 0.14$, $MSE = .02$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution as the dependent variable (see Table 6). A main effect of distraction level was found [$F(3,96) = 3.43$, $MSE = .01$]. Pairwise LSD tests found that although low and medium distraction levels yielded greater incubation resolution rates than did the high distraction level, these differences were not significant. The continuous work condition produced significantly greater resolution rates than did the high distraction condition and was marginally greater than the low (p = .08) and medium (p = .08) conditions (see Figure 2).

Table 6

Exp. 2: Solution Rates for RAT Problems in Blocking Trials

Distraction level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
Continuous work	.25 (.03)	.13 (.02)
Low	.25 (.03)	.07 (.02)
Medium	.26 (.03)	.07 (.02)
High	.27 (.03)	.03 (.02)

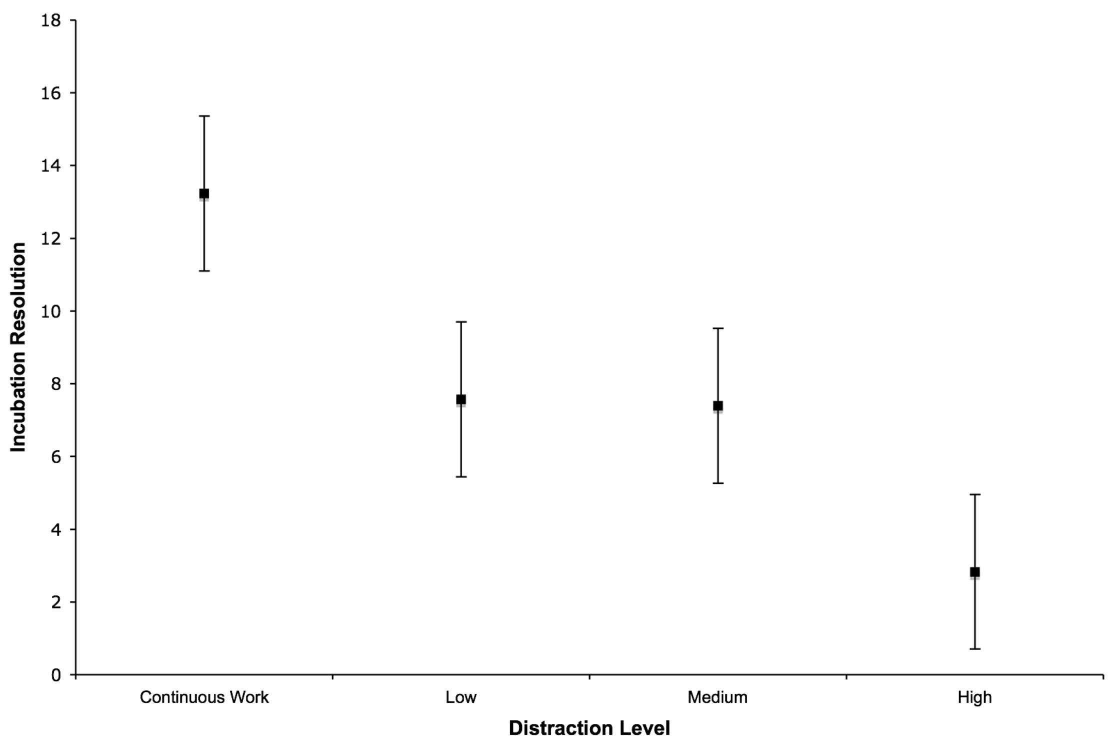


Figure 2. Experiment 2: Resolution of Blocking Trials

A one-way ANOVA analyzed the effects of level of distraction using the number of blockers incorrectly given for an answer as the dependent variable. No main effect of distraction level was found [$F(3,96) = 1.18$, $MSE = 1.43$]. The continuous work ($M = 1.20$, $SE = .24$), low ($M = 1.40$, $SE = .24$), medium ($M = 1.80$, $SE = .24$), and high ($M = 1.32$, $SE = .24$) conditions answered the RAT problems with a blocker on approximately 12% of the blocking trials.

A manipulation check examined if the experimentally manipulated distraction levels indeed caused different amounts of distraction. A one-way ANOVA analyzed the effects of level of distraction using the error rate (proportion of incorrect Digit Monitoring Task counts) as the dependent variable[3]. There appeared to be no pattern for the proportion of trials resulting in a digit monitoring error across the low ($M = .30$, $SE = .04$), medium ($M = .30$, $SE = .04$), and high ($M = .25$, $SE = .04$) conditions. No main effect of distraction level was found [$F(2,72) = 0.53$, $MSE = 0.04$]. A conditional Digit Monitoring Task performance analysis can be found in Table 7. This table shows that in the low and high distraction levels, the rate of committing a monitoring error increased from focusing solely on the Digit Monitoring Task (Initially solved) to a second attempt at solution (No resolution) to actually resolving the RAT problem during the distraction interval (Incubation resolution). The error rate in the medium distraction level was consistent for all three possible RAT problem outcomes.

[3] ANOVA's on Error Rate for Unrelated and Helpful trials were also performed, both yielding no main effect of distraction level.

Table 7

Error Rates on Digit Monitoring Task for Blocking Trials

Distraction level	RAT problem status		
	Initially solved	No resolution	Incubation resolution
Low	0.30	0.32	0.44
Medium	0.32	0.31	0.33
High	0.21	0.27	0.58

Unrelated Trials

A one-way ANOVA analyzed the effects of level of distraction, using the proportions of RAT problems solved initially as the dependent variable (see Table 8). No main effect of distraction level was found [$F(3,96) = 0.40$, $MSE = .05$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution as the dependent variable (see Table 8). No main effect of distraction level was found [$F(3,95) = 1.65$, $MSE = .03$].

Table 8

Solution Rates for RAT Problems in Unrelated Trials

Distraction level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
Continuous work	.32 (.05)	.16 (.03)
Low	.39 (.05)	.07 (.03)
Medium	.37 (.05)	.08 (.03)
High	.37 (.05)	.06 (.03)

Helpful Trials

A one-way ANOVA analyzed the effects of level of distraction, using the proportions of RAT problems solved initially as the dependent variable (see Table 9). No main effect of distraction level was found [$F(3,96) = 1.34$, $MSE = .07$].

Another one-way ANOVA analyzed the effects of level of distraction using incubation resolution as the dependent variable (see Table 9). A main effect of distraction level was found [$F(3,88) = 7.17$, $MSE = .10$]. Pairwise LSD tests revealed that the continuous work level ($M = .51$, $SE = .07$) was significantly greater than the low ($M = .16$, $SE = .06$), medium ($M = .14$, $SE = .07$), and high ($M = .18$, $SE = .07$) distraction levels.

Table 9

Solution Rates for RAT Problems in Helpful Trials

Distraction level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
Continuous work	.49 (.05)	.51 (.07)
Low	.63 (.05)	.16 (.06)
Medium	.61 (.05)	.14 (.07)
High	.56 (.05)	.18 (.07)

Discussion

In Experiment 2, the same procedure from Experiment 1 was used. In addition to the three levels of distraction, a condition was tested in which participants viewed the RAT problem continuously without a distraction period. Thus, Experiment 2 was essentially a replication of Experiment 1. While similar results were found in the two experiments, there was some disparity between the two experiments in the resolution rates for the low and medium conditions. It is not known if one or more of the results is due to an extraneous factor (e.g., subject population). Because the origin of the disparity may be due to average chance, it makes sense to average the resolution rates of the two experiments. The medium (M = .08, SE = .02) distraction level has greater incubation resolution than the low (M = .06, SE = .02) and the high (M = .02, SE = .02) distraction levels. This result is supportive of the Withdrawal of Attention hypothesis.

One of the goals of Experiment 2 was to test a new control condition so as to provide a comparison to the control condition in Experiment 1. The continuous work condition in Experiment 2 and the control condition in Experiment 1 yielded the same resolution rate for Blocking trials and almost the same rate for Unrelated trials. Thus, it appears that participants in the control condition were not focusing on digit monitoring, but rather engaged in a continuous attempt to resolve the RAT problem during the distraction interval. This is supported by the no incubation condition in Experiment 1, a condition that was similar to the continuous work condition, only shorter in duration.

While these two experiments found the medium distraction level to yield the greatest incubation resolution, continuous work on the problem was better for problem resolution. In both experiments for all three trial types, the control/continuous work condition had greater resolution rates than the three distraction levels. The Withdrawal of Attention hypothesis predicts a moderate amount of distraction during an interval would be optimal so that the person would forget the intrusion, yet still have cognitive resources available to work towards resolving the problem. It seems that this hypothesis is only applicable to when a person is distracted. For the best resolution, all distraction should be avoided.

Like Experiment 1, a manipulation check for the distraction levels (low, medium, high) was analyzed using the rate of committing a digit monitoring error. Participants in all three levels committed an error at approximately the same rate. When analyzing the error rate by RAT problem solution (see Table 7), a result similar to Experiment 1 is found. Again, it appears that resolving a RAT problem led participants to commit a digit monitoring error.

For the Unrelated trials, no effect of distraction level was found for the proportion of RAT problems solved initially or for the incubation resolution rates. However, for Helpful trials, a main effect of distraction level was found for incubation resolution rates. The continuous work condition yielded far greater resolution rates than the low, medium, and high conditions. This is not unexpected. An extrapolation of the resolution rate for the no incubation condition (.26) in Experiment 1 could yield a rate close to that found in the continuous work condition (.51) in Experiment 2. Because there are no blockers in Helpful trials, more time to solve the problem should yield greater resolution rates.

The results of the Blocking trials in Experiment 2 did not precisely replicate the results in Experiment 1. However, the two experiments presented supporting evidence for the Withdrawal of Attention hypothesis. The pattern of results does not conform to the predictions of the Forgetting Fixation hypothesis nor the Incremental Work hypothesis. The Forgetting Fixation hypothesis would predict that the greatest resolution occurs with high condition. However, the high condition yielded the lowest resolution in both experiments. The Incremental Work hypothesis would predict that the less distracted a person is, the more work they are able to perform incremental work towards solving the problem. The results clearly do not show an increase in resolution from the high to medium to low levels. However, with Helpful trials, continuous work appears to be of more benefit. This is logical, as distraction would cause the participant to forget the helpful hint. It is important to remember that these three hypotheses were formed for incubation intervals, not distraction intervals. A much different pattern may emerge when the RAT problem is removed from a participant's sight during the interval. Therefore, Experiments 3 and 4 will test these three hypotheses using a paradigm involving a true incubation interval.

EXPERIMENT 3

The purpose of Experiment 3 was to test the paradigm used in Experiment 1 on true incubation periods. Experiments 1 and 2 were distraction experiments because the RAT problem was present during the incubation interval. True incubation experiments involve the unsolved problem being removed from the participant. Thus, in the incubation interval, the RAT problem was removed from the screen, forcing the participant to focus solely on incubation task (monitoring patterns of digits). Like Experiment 1, three attention levels and two comparison conditions were tested. It was hypothesized that a similar result to Experiment 1 would be found. Namely, withdrawing a moderate amount of attention during incubation would result in a much greater incubation effect than withdrawing a small or great amount of attention.

Method

Participants

Participants for this study came from an introductory psychology course and received credit towards course completion. These students were given the option of signing up for this experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 121 students participated in this experiment and were randomly selected into one of the five conditions: low, medium, high, control, and no incubation.

Materials

The same materials from Experiment 1 were used in Experiment 3.

Design and Procedure

The same procedure from Experiment 1 was used in Experiment 3. The only exceptions were that the RAT problem was not displayed during the Digit Monitoring Task on each trial and that four fewer test trials were used than the test trials in Experiment 1.

Twenty-four trials were constructed for this experiment. Of these, 10 were classified as "Blocking", five as "Helpful" and five as "Unrelated." The remaining four trials were used as examples (one Blocking, one Helpful, and two Unrelated) to aid in participants' procedural knowledge of the experimental tasks.

Results

Blocking Trials

A one-way ANOVA analyzed the effects of level of incubation (no incubation, control, low, medium, high), a between-subjects variable, using the proportions of RAT problems solved initially as the dependent variable (see Table 10). No main effect of incubation level was found [$F(4,116) = 0.51$, $MSE = .02$].

Another one-way ANOVA analyzed the effects of level of incubation using incubation resolution as the dependent variable. A main effect of distraction level was found [$F(4,116) = 3.25$, $MSE = .01$]. Pairwise LSD tests found that there was no significant difference between the low, medium, and high incubation levels. The control and low conditions yielded greater incubation resolution rates than the no incubation condition. The control condition also had a greater incubation resolution rate than the medium condition (see Figure 3).

Table 10

Solution Rates for RAT Problems in Blocking Trials

Incubation level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
No incubation	.29 (.03)	.05 (.02)
Control	.31 (.02)	.16 (.02)
Low	.32 (.03)	.12 (.02)
Medium	.30 (.03)	.08 (.02)
High	.34 (.03)	.10 (.03)

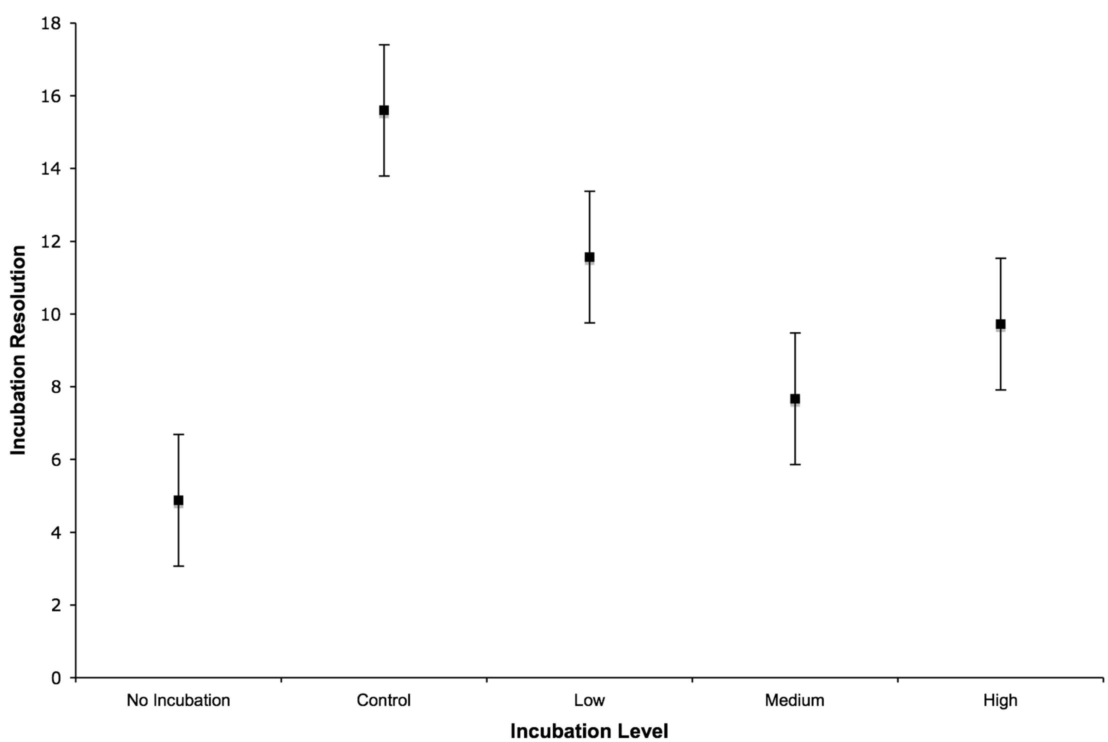


Figure 3. Experiment 3: Resolution of Blocking Trials

A one-way ANOVA analyzed the effects of level of incubation using the number of blockers incorrectly given for an answer as the dependent variable. No main effect of incubation level was found [$F(4,116) = 1.33$, $MSE = 1.32$]. The no incubation ($M = 0.84$, $SE = .23$), control ($M = 1.03$, $SE = .21$), low ($M = 0.52$, $SE = .24$), medium ($M = 1.27$, $SE = .25$) and high ($M = 0.86$, $SE = .25$) conditions answered the RAT problems with a blocker on approximately 9% of the blocking trials.

A manipulation check was run to examine if the experimentally manipulated incubation levels indeed caused different amounts of distraction. A one-way ANOVA analyzed the effects of level of incubation using the error rate (proportion of incorrect Digit Monitoring Task counts) as the dependent variable[4]. There appeared to be no pattern for the proportion of trials resulting in a digit monitoring error across the low ($M = .12$, $SE = .03$), medium ($M = .20$, $SE = .03$), and high ($M = .11$, $SE = .03$) conditions. No main effect of incubation level was found [$F(2,63) = 1.95$, $MSE = 0.02$]. A conditional Digit Monitoring Task performance analysis can be found in Table 11. This table shows that the rate of committing a monitoring error remained fairly constant from focusing solely on the Digit Monitoring Task (Initially solved) to a second attempt at solution (No resolution) to actually resolving the RAT problem during the incubation interval (Incubation resolution).

[4] ANOVA's on Error Rate for Unrelated and Helpful trials were also performed, both yielding no main effect of distraction level.

Table 11

Error Rates on Digit Monitoring Task for Blocking Trials

Incubation level	RAT problem status		
	Initially solved	No resolution	Incubation resolution
Low	0.07	0.13	0.15
Medium	0.24	0.16	0.27
High	0.09	0.13	0.10

Unrelated Trials

A one-way ANOVA analyzed the effects of level of incubation (no incubation, control, low, medium, high), using the proportions of RAT problems solved initially as the dependent variable (see Table 12). No main effect of distraction level was found [$F(4,116) = 0.06$, $MSE = .07$].

Another one-way ANOVA analyzed the effects of level of incubation using incubation resolution as the dependent variable (see Table 12). No main effect of distraction level was found [$F(4,114) = 1.85$, $MSE = .06$].

Table 12

Solution Rates for RAT Problems in Unrelated Trials

Incubation level	Proportion Solved Initially (SE)	Incubation Resolution (SE)
No incubation	.38 (.05)	.16 (.05)
Control	.37 (.05)	.29 (.05)
Low	.38 (.05)	.23 (.05)
Medium	.39 (.06)	.14 (.05)
High	.41 (.06)	.12 (.06)

Helpful Trials

A one-way ANOVA analyzed the effects of level of incubation (no incubation, control, low, medium, high), using the proportions of RAT problems solved initially as the dependent variable (see Table 13). No main effect of distraction level was found [$F(4,116) = 0.10$, $MSE = .08$].

Another one-way ANOVA analyzed the effects of level of incubation using incubation resolution as the dependent variable (see Table 13). A main effect of incubation level was found [$F(4,88) = 3.08$, $MSE = .13$]. Pairwise LSD tests revealed that the control, low, medium, and high conditions all yielded greater incubation resolution rates than the no incubation condition.

Table 13

Solution Rates for RAT Problems in Helpful Trials

Incubation level	Proportion Solved Initially (*SE*)	Incubation Resolution (*SE*)
No incubation	.69 (.05)	.03 (.08)
Control	.66 (.05)	.38 (.08)
Low	.65 (.06)	.35 (.08)
Medium	.66 (.06)	.28 (.08)
High	.64 (.06)	.35 (.09)

Discussion

Experiment 3 used the same procedure as the previous two experiments except that Experiment 3 contained an incubation period in which the RAT problem was not displayed on the monitor. In contrast to Experiment 1 and 2, which were distraction experiments, there was no significant difference in resolution rates between the low, medium, and high incubation levels in Experiment 3. An incubation effect was observed with the control and low conditions yielding greater incubation resolution than the no incubation condition. Incubation effects are not always observed (Olton, 1979; Olton & Johnson, 1976). The present experiment is the first one known to produce an incubation effect using a trial-by-trial paradigm.

The control condition yielded the highest resolution rates of the five conditions (although only significantly greater than the no incubation and the low conditions). The resolution data cannot clearly support the predictions of any of the three hypotheses. At first, it would seem to lend evidence for the Incremental Work hypothesis. The control condition allowed for spreading activation to occur, leading to solution. However, this hypothesis is based on chance encounters with hints during the incubation intervals (Bowers *et al*., 1990; Yaniv & Meyer, 1987), something that could not occur in the experimental setting. The results could also potentially be explained by the Forgetting Fixation hypothesis. This hypothesis predicts the greatest resolution when the blocking associate is weakened and the desired associate is activated (Smith, 1995). There is the possibility that the control condition was engaging enough to weaken the blocker, however, this hypothesis would not predict the lack of benefit from the added demands in the low, medium, and high conditions. The results in Experiment 3 results can also be explained by the Withdrawal of Attention hypothesis. It is possible that control condition was demanding enough to remove attention from the blocker and the low, medium, and high conditions were too demanding to allow for optimal resolution to occur. While, the present experiment was designed to match the low condition with the Incremental Work hypothesis, the medium condition with Withdrawal of Attention hypothesis, and the high condition with the Forgetting Fixation hypothesis, it is important to realize that the labels assigned to the three conditions is arbitrary. A condition in which a participant is required to monitor for two odd digits appearing in-a-row ("low condition") could in fact be quite demanding. Due to error rates not varying between the low, medium, and high conditions, it is impossible to make conclusions regarding this.

A manipulation check was also run to examine if the incubation levels varied in difficulty on the Digit Monitoring Task. There was no pattern of committing a digit monitoring error between the low, medium, and high conditions. When analyzing the error rate by RAT problem performance (see Table 11), a different result from Experiments 1 and 2 is found. The rate of committing a digit monitoring error only slightly increases from solving the RAT problem initially to resolving the problem during incubation. This is contrast to the two distraction experiments where there was a large, steady increase in the error rate from solving the RAT problem initially to attempting it during the distraction interval to resolving the problem during the interval. This result shows supporting evidence that one should not compare incubation and distraction problems. While both types of intervals lead towards RAT problem resolution, it is evident that participants are focusing solely on the RAT problem during incubation intervals while the presence of RAT problems in distraction intervals do in fact distract the participant.

For the Unrelated trials, there was no effect of incubation level on the proportion of RAT problems solved initially or for the incubation resolution. However, in comparison to the data from Experiments 1 and 2, the resolution rates are higher following an incubation interval compared to a distraction interval.

Among Helpful trials, an incubation effect was found where the control, low, medium, and high conditions all yielded far greater resolution rates than the no incubation condition. This is in contrast to Helpful trials of the no incubation and the control conditions in Experiments 1 and 2. In those experiments, it was hypothesized that continuous work was optimal for resolution and that more distraction led to less resolution. This does not seem to be the case here, where incubation is beneficial for problem resolution. Also, compared with the two distraction experiments, the resolution rates are higher in the present experiment. Thus, it appears that for participants who do not remember the cue instantly in the RAT problem's first presentation, benefit more from an incubation interval than a distraction interval.

Experiment 3 has demonstrated an incubation effect for Blocking trials. When compared to the data from the previous two experiments, an incubation effect is also shown for Helpful and Unrelated trials. Thus, Experiment 3 was successful in demonstrating incubation effects using a trial-by-trial paradigm. At this point, it is not clear which hypothesis of incubation is correct. What is needed is an experiment that examines if initial fixation is a necessity for observing incubation effects. Furthermore, it would be easier to observe differences between the low, medium, and high incubation levels if resolution rates were raised. The incubation resolution rates for Blocking trials in all three experiments were between .02 and .12, indicating a possible floor effect. Experiment 4 will attempt to address these two concerns.

EXPERIMENT 4

The goal of Experiment 4 was to further examine the effects of attentional demands during true incubation periods. Furthermore, the experiment was designed to investigate if the procedure in Experiments 1-3 induces a fixation effect, and if incubation resolution depends upon initial fixation. By means of counter-balancing, some participants received a specific RAT problem in a blocking trial (prime a fixated "Blocker" word in the preceding Two-Word Phrase Task), whereas other participants would receive that RAT problem in an unrelated trial (no "Blocker" word primed).

One of the possible problems with the previous three experiments was that a floor effect was occurring with incubation effects. In an attempt to alleviate this, in Experiment 4 participants were incidentally primed with the same RAT solution words, which were presented on an affective judgment rating scale prior to the experiment. Solutions to some of the RAT problems (dependent upon counterbalance version) were mixed in with filler items.

Method

Participants

Participants for this study came from an introductory psychology course and received credit towards course completion. These students were given the option of signing up for this experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 60 students participated in this experiment and were randomly selected into one of the three conditions: low, medium, and high.

Materials

The same materials from Experiment 1 were used in Experiment 4. Additionally, an "affective judgment scale" was used. In this task, 30 words were listed on paper. Participants were asked to rate on a scale of -3 to +3 how much they like each word/concept by circling the numeric value (+3 indicating "highly like" and -3 indicating "highly dislike").

Design and Procedure

The same procedure from Experiment 3 was used in Experiment 4.

This experiment employed a counterbalanced (CB) design in which each condition contained four counterbalanced groups (see Table 14). This was conducted using a 2 (priming: primed vs. not primed) X 2 (blocking: blocked vs. not blocked) X 4 (counterbalance groups) design. "Priming," a within-subject variable, refers to whether or not the solution to the RAT problem was primed in the affective judgment scale. "Blocking," another within-subject variable refers to whether or not the RAT problem was preceded by a Two-Word Phrase Task containing a "blocker". There are 12 critical RAT problems involving counterbalancing. These 12 RAT problems are assigned to four treatment conditions (with three problems in each treatment condition): Primed & Blocked; Primed & Not Blocked; Not Primed & Blocked; Not Primed & Not Blocked. Each of the treatment conditions contained three RAT problems and the problems were rotated so that they were in each treatment condition. The items assigned to the priming and blocking conditions were counterbalanced across groups. The counterbalancing scheme is shown in Table 14.

Table 14

Experiment 4 Stimuli Used in Each Counterbalance (CB) Group

	RAT Solutions Primed		RAT Solutions Not Primed		
	Blocked	Not Blocked	Blocked	Not Blocked	Helpful
CB1	1,2,3	4,5,6	7,8,9	10,11,12	13,14,15,16,17,18
CB2	4,5,6	7,8,9	10,11,12	1,2,3	13,14,15,16,17,18
CB3	7,8,9	10,11,12	1,2,3	4,5,6	13,14,15,16,17,18
CB4	10,11,12	1,2,3	4,5,6	7,8,9	13,14,15,16,17,18

Due to the design, counterbalance groups CB1 and CB3 share the same trials; therefore, they both received the same PowerPoint presentation. Likewise, counterbalance groups CB2 and CB4 received the same PowerPoint presentation. In addition to four example trials (one Helpful, one Blocking, and two Unrelated), each presentation contained six Blocking trials, six Helpful trials, and six Unrelated trials. The difference between the trials in CB1/CB3 and CB2/CB4 was that RAT problems Blocking trials were switched with RAT problems in the Unrelated trials. This was done by taking the unrelated trials in CB1/CB3 and using an associated Two-Word Phrase Task to prime a Blocker (see Exp. 1) and thus transforming them into Blocking trials. Similarly, the Blocking trials in CB1 and CB3 were given unrelated words in their Two-Word Phrase Task to make them Unrelated (not blocked) trials.

Sessions for Experiment 4 contained participants from multiple counterbalance groups. Participants from CB1 and CB3 were run together as were participants from CB2 and CB4 because each pair shared the same trials/presentation.

The four counterbalance groups also differed in their affective judgment rating scales given to participants (see Table 14). In each scale, three Blocking trial RAT answers and three Unrelated trial RAT answers were mixed in with the 24 filler words. This was done to prime the answers to raise solution rates.

In each of the three conditions, participants were given three minutes to complete the affective judgment scale. Upon completion, these scales were collected so that participants were unable to view the words. Next, the remainder of the procedure used in Experiment 4 was the same procedure as described for Experiment 3. Participants received instructions on each of the three types of tasks and performed four example trials before completing the 18 test trials. The same time limits used in Experiment 3 were imposed for each task in Experiment 4.

Results

Blocking and Unrelated (Not Blocked) Trials

A 2 (blocking vs. unrelated) X 2 (primed vs. not primed) X 4 (CB1, CB2, CB3, CB4) X 3 (low, medium, high) mixed ANOVA was calculated using the proportions of RAT problems solved initially as the dependent variable (see Tables 15, 16, and 17). Trial type (blocking vs. unrelated) and priming (primed vs. not primed) were within-subject variables. Counterbalancing group (CB1, CB2, CB3, CB4) and incubation level (low, medium, high) were between-subject variables. There was a significant main effect of incubation level [$F(2,48) = 4.36$, $MSE = .06$]. Pairwise LSD tests revealed that participants in the medium condition solved fewer RAT problems initially than participants in the low and high conditions. Unexpectedly, a marginal main effect of counterbalancing group [$F(3,48) = 2.53$, $MSE = .06$, $p = .08$] was also found. No main effects of priming [$F(1,48) = 2.23$, $MSE = .05$] or of trial type [$F(1,48) = 2.91$, $MSE = .04$] were found. The priming X counterbalancing interaction was significant [$F(2,48) = 0.87$, $MSE = .05$]. The trial type X counterbalancing interaction was significant [$F(3,48) = 3.42$, $MSE = .04$]. The priming X trial type X counterbalancing interaction was marginally significant [$F(3,48) = 2.64$, $MSE = .04$, $p = .06$]. All other interactions calculated were not significant (see Appendix D).

A 2 (blocking vs. unrelated) X 2 (primed vs. not primed) X 4 (CB1, CB2, CB3, CB4) X 3 (low, medium, high) mixed ANOVA was calculated using the incubation resolution as the dependent variable. There was no main effect of trial type [$F(1,46) = 0.01$, $MSE = .03$], priming [$F(1,46) = 0.19$, $MSE = .04$], counterbalancing [$F(3,46) = 1.77$, $MSE = .03$], or incubation level [$F(2,46) = 0.05$, $MSE = .03$]. The priming X trial type X incubation level interaction was marginally significant [$F(2,46) = 2.66$, $MSE = .05$, $p = .08$]. All other interactions were not significant (see Appendix D).

Table 15

Solution Rates for RAT Problems in Blocking and Unrelated Trials by Incubation Level

Variable		Proportion Solved Initially (*SE*)	Incubation Resolution (*SE*)
Incubation level	Low	.32 (.03)	.09 (.02)
	Medium	.22 (.03)	.09 (.02)
	High	.33 (.03)	.09 (.02)

Table 16

Solution Rates for RAT Problems in Blocking and Unrelated Trials by Priming and Counterbalancing Group

RAT Problem Status		CB1	CB2	CB3	CB4
Proportion Solved Initially	Primed	.28 (.05)	.28 (.04)	.42 (.03)	.27 (.05)
	Not Primed	.36 (.04)	.26 (.05)	.27 (.05)	.19 (.05)
Incubation Resolution	Primed	.08 (.03)	.07 (.02)	.04 (.02)	.10 (.02)
	Not Primed	.06 (.02)	.04 (.02)	.04 (.02)	.10 (.04)

Table 17

Solution Rates for RAT Problems in Blocking and Unrelated Trials by Trial Type and Counterbalancing Group

Solution		CB1	CB2	CB3	CB4
Proportion Solved Initially	Blocking	.26 (.03)	.29 (.05)	.28 (.04)	.24 (.05)
	Unrelated	.38 (.05)	.24 (.04)	.41 (.04)	.21 (.05)
Incubation Resolution	Blocking	.08 (.02)	.04 (.02)	.04 (.02)	.10 (.03)
	Unrelated	.06 (.03)	.07 (.02)	.04 (.02)	.10 (.02)

A one-way ANOVA analyzed the effects of level of distraction using the number of blockers incorrectly given for an answer as the dependent variable. No main effect of distraction level was found [$F(2,57) = 0.99$, $MSE = 0.66$]. The low ($M = 0.40$, $SE = .18$), medium (M = 0.30, SE = .18), and high (M = 0.65, SE = .18) conditions answered the RAT problems with a blocker on approximately 8% of the blocking trials.

A manipulation check was run to examine if the experimentally manipulated incubation levels indeed caused different amounts of distraction. A one-way ANOVA analyzed the effects of level of incubation using the error rate (proportion of incorrect Digit Monitoring Task counts) in blocking trials as the dependent variable[5]. There appeared to be no pattern for the proportion of trials resulting in a digit monitoring error across the low (M = .16, SE = .04), medium (M = .11, SE = .04), and high (M = .18, SE = .04) conditions. No main effect of incubation level was found [$F(2,57) = 0.82$, MSE = 0.03]. A conditional Digit Monitoring Task performance analysis can be found in Table 18. This table shows that for low incubation level, the rate of committing a monitoring error remained fairly constant from focusing solely on the Digit Monitoring Task (Initially solved) to a second attempt at solution (No resolution) to actually resolving the RAT problem during the incubation interval (Incubation resolution). The error rate for medium and high incubation levels showed no clear pattern.

[5] ANOVA's on Error Rate for Unrelated and Helpful trials were also performed, both yielding no main effect of distraction level.

Table 18

Error Rate on Digit Monitoring Task for Blocking Trials

Distraction level	RAT problem status		
	Initially solved	No resolution	Incubation resolution
Low	0.20	0.16	0.17
Medium	0.17	0.08	0.30
High	0.18	0.20	0.00

Helpful Trials

A one-way ANOVA analyzed the effects of level of incubation (low, medium, high), using the proportions of RAT problems solved initially as the dependent variable (see Table 19). A marginal main effect of distraction level was found [$F(2,57) = 2.62$, $MSE = .08$]. Pairwise LSD tests revealed that participants in the medium level ($M = .47$, $SE = .06$) solved a significantly lower proportion of RAT problems initially than participants in the low level ($M = .65$, $SE = .06$) and marginally lower than participants in the high level ($M = .63$, $SE = .06$).

Another one-way ANOVA analyzed the effects of level of incubation using incubation resolution as the dependent variable (see Table 19). No main effect of incubation level was found [$F(2,49) = 1.37$, $MSE = .08$].

Table 19

Solution Rates for RAT Problems in Helpful Trials

Incubation level	Proportion Solved Initially (*SE*)	Incubation Resolution (*SE*)
Low	.65 (.06)	.24 (.07)
Medium	.47 (.06)	.15 (.06)
High	.63 (.06)	.09 (.06)

Discussion

In Experiment 4, levels of attention demands were manipulated during an incubation interval. Additionally, a counterbalancing scheme was used to detect if there was a fixation effect as well as if priming a solution could raise incubation resolution rates. The experiment found no main effect of attentional demands on resolution rates. Furthermore, when analyzing only the Blocking trials, there is a pattern (see Figure 4) weaker than what was observed in Experiment 1 (see Figure 1). The results from Experiments 3 and 4 found no differences in resolution rates between low, medium, and high attention demands during incubation intervals. Thus, this experiment was not able to conclude which of the three hypotheses are more accurate.

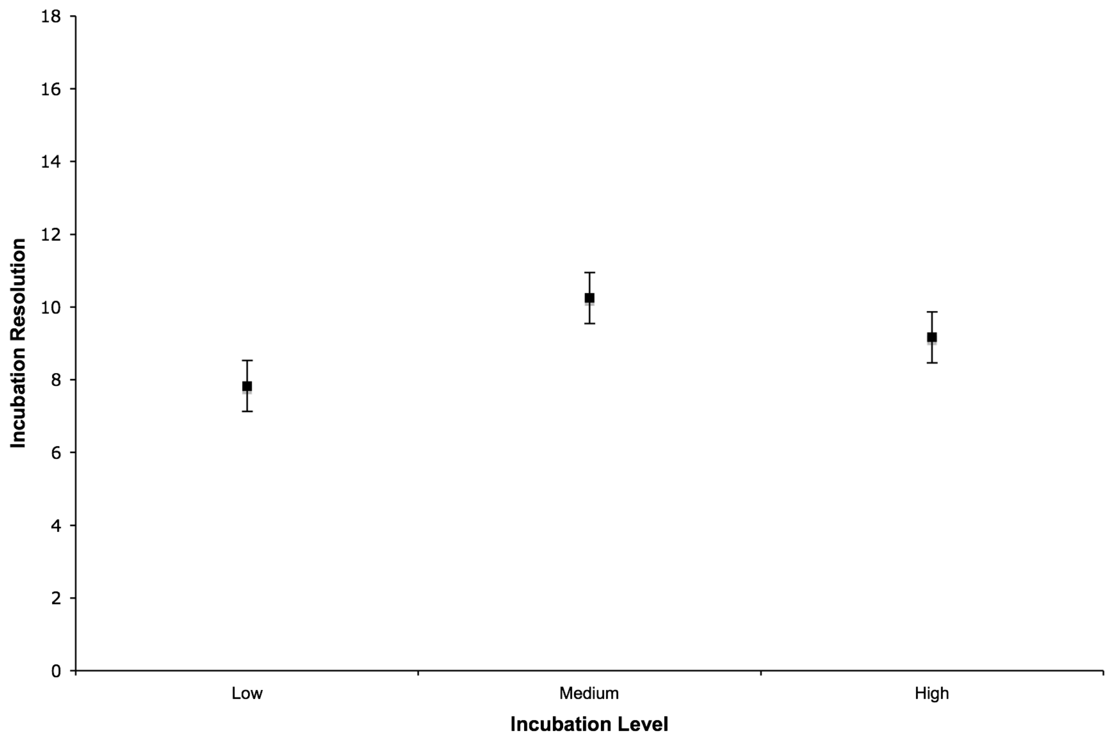


Figure 4. Experiment 4: Resolution of Blocking Trials

Priming a solution in the preceding affective rating judgment task was only minimally effective in raising resolution rates (Δ = .02). Since resolution rates remained relatively low (.09), the possibility remains that a floor effect caused the three incubation levels to not differ. An unexpected result was found in that the resolution rates for the Unrelated (not blocked) trials were no higher than the resolution rates for the Blocking trials. This is in contrast to all Unrelated-Blocking comparisons for low, medium, and high conditions for the previous three experiments. The purpose of counterbalancing the same RAT problems to appear as Blocking and Unrelated trials was to examine if participant fixation on a blocking concept was a necessity for observing incubation effects. Observing such a result would lend supporting evidence for the Forgetting

Fixation hypothesis. Since there was no difference in resolution rates for the trial type variable, one cannot conclude that incubation effects are the result of overcoming fixation on an undesired concept. This is in contrast to the conclusion by Smith and Blankenship (1989) who found that resolution rates increased at approximately the same rate as memory of a blocking clue decreased. As mentioned in Experiment 3, their result may have been an artifact of more time allowing problem resolution and causing simple memory decay.

Like the previous three experiments, the proportion of RAT problems solved initially was analyzed. The medium condition solved the RAT problems at a significantly lower rate than the other two conditions. This was unexpected because the only between-subject manipulation (digit monitoring) occurred following the initial RAT attempt. This result indicates that there might have been a problem with the participants in the medium condition (e.g., ability). Had their ability been at the same level as the other two conditions, it is possible that the slight curvilinear result observed for Blocking trials might have been more similar to that found in Experiment 1. In the analysis for proportion of RAT problems solved initially, a slight benefit was found for trials that were primed as well as for Unrelated trials. The increase in proportion solved initially ($\Delta = .04$) and the increase in incubation resolution ($\Delta = .02$) was so small for primed trials, one can conclude that the priming task was ineffective for raising solution and resolution rates. Instead of using an affective rating judgment task, future experiments should prime solutions by using a task that requires participants to think about the concept longer than two seconds.

Unrelated trials were only initially solved at a slightly higher rate ($\Delta = .04$) than Blocking trials. Like, the incubation resolution rates, it is not known why there was not as much disparity between these type of trials compared with the previous three experiments. This is most likely an artifact of one of three reasons: (1) Some of the RAT problems for Experiment 4 differed from the previous three experiments. (2) The problematic participants in the medium condition skewed the results. Among the three conditions, the medium condition had the smallest disparity between Unrelated and Blocking trials. (3) Participants are not becoming fixated on the blocker word. This is not likely as 8% of the Blocking trials were answered with a blocker. Interestingly, the medium condition yielded the fewest blockers (although, not significant). Thus, it appears that there was a problem with participants in the medium condition in Experiment 4.

A manipulation check was also run to examine if the incubation levels varied in difficulty on the Digit Monitoring Task. There was no pattern of committing a digit monitoring error between the low, medium, and high conditions. When analyzing the error rate by RAT problem performance (see Table 18), a similar result to Experiment 3 is found. Both incubation experiments show no strong pattern of the digit monitoring error rate increasing from when the RAT problem is solved initially to when it is resolved following the incubation interval. The lack of such a pattern is indicative that the RAT problem has been removed from the attention of the participant during the incubation.

While not the focus of Experiment 4, the Helpful trials were analyzed. Like the unrelated and blocking trials, the low and high conditions solved the RAT problems initially at a far greater rate than the medium condition. This is more evidence that the participants in the medium condition are outliers. There was no main effect of incubation level for incubation resolution; however, there is a trend in which the low condition (.24) had a higher rate than the medium (.15) and the high condition (.09). This pattern is similar to that found for Helpful trials in the distraction experiments. For Helpful trials in which the solution is presented immediately preceding the RAT problem, resolution tends to be higher the less distracted a participant is. This is intuitive because distracting a person during an incubation or distraction interval would cause them to forget the helpful clue for solving the problem.

Experiment 4 attempted to further investigate the prediction of the three hypotheses, examine if fixation was a necessity for observing incubation effects, and raise resolution rates via priming. Due to the priming task being ineffective and the sample of participants used for the medium condition, Experiment 4 was did not produce clear results. Although not the primary focus of Experiment 4, a clearer picture emerged of the mechanisms underlying problems involving helpful clues. Perhaps, with an improved priming task and a different set of participants, answers regarding mechanisms of Blocking trials can be found.

SUMMARY AND CONCLUSIONS

This series of experiments sought to better understand the mechanisms underlying resolution of problems during incubation as well as distraction intervals. The Incremental Work hypothesis, the Withdrawal of Attention hypothesis, and the Forgetting Fixation hypothesis make independent predictions regarding the mechanisms of incubation.

Experiments 1 and 2 examined resolution rates following distraction intervals in which the problem remained on the screen. No incubation effect was observed in these two experiments; the distraction intervals did not facilitate greater problem resolution than did a condition in which there was no distraction interval. An incubation effect should not be expected because these were experiments in which the problem was distracted, not put completely aside. That participants committed more digit monitoring errors when they resolved the problems during the interval shows that the problem was not completely put aside. Although no incubation effect occurred in Experiments 1 and 2, the distracting task was beneficial for resolution. The more distracted a participant was, as measured by the digit monitoring error rate, the greater the rate of resolution. In Experiments 1 and 2, a trend emerged in which the medium condition yielded greater resolution rates than the low and high conditions for Blocking trials. This result does not fit the predicted patterns of the Incremental Work hypothesis or the Forgetting Fixation hypothesis (see Appendix B). Thus, for problems involving distraction intervals, it appears that it is best explained by the Withdrawal of Attention hypothesis. Problems that cause people to reach an impasse in their initial attempts due to fixation on a blocking concept are best solved when people are distracted enough to forget the blocking concept, yet still have enough attentional resources remaining to solve the problem. From these set of experiments it is unknown how much of one's cognitive resources should be devoted towards problem resolution and how much should be withdrawn by the distracting task. Perhaps there is no finite formula for problem resolution (i.e. 40% distraction and 60% solution attempt). Rather, the optimal amount of distraction depends on the type of problem and how strong the fixation is.

For Helpful trials in Experiments 1 and 2, resolution was higher in the control and continuous work conditions than the low, medium, and high conditions. The results for distraction interval problems involving helpful cues are best explained by the Incremental Work hypothesis. For these types of problems, more distracting intervals caused participants to resolve fewer problems. This is an intuitive result. If a person is presented with a helpful clue to the problem, he or she is more likely to find a solution when they are not distracted from thinking about the clue.

Experiments 3 and 4 examined resolution rates following incubation intervals in which the problem was removed from the screen. An incubation effect was found; removing the problem from a participant's attention was more beneficial for resolution than was a continuous solution attempt. The conditional digit monitoring error analysis provided evidence that the problem was removed from the participants' attention. The present study offers another demonstration of incubation effects in a laboratory setting, something not frequently shown (Olton, 1979). Although an incubation effect was demonstrated in Experiments 3 and 4, no clear pattern emerged for resolution rates on

Blocking trials for the low, medium, and high conditions. It was hoped that the results would have produced a clear trend where resolution increased or decreased across conditions or a trend in which the medium condition outperformed the other two conditions (like the distraction experiments). Due to the lack of such a trend, this series of experiments were unable to come to a conclusion regarding the mechanisms of problems involving incubation intervals. It is likely that problems with floor effects and population samples caused the data to not be easily interpretable. There also does exist the possibility that optimal incubation resolution is not a function of attentional demands. This would explain why there has not been consistency in incubation research. A more precise manipulation of attention during incubation would shed light on the possibility.

One of the goals of the present study was to examine if the mechanisms underlying problem resolution are similar in incubation and distraction intervals. This was because resolution of problems when they are distracted and incubated is easily observable in the real world. From the conditional error rate analysis for the four experiments, it was observed that during distraction intervals participants are indeed dividing their attention between the problem and the interval task. For incubation intervals, participants appear to be focusing solely on the incubation task even when they resolve the problem during incubation. Not only were the mechanisms different, so was the outcome. Resolution rates were higher following incubation intervals than distraction intervals. This is evidence of an incubation effect and shows that while distraction can lead to greater resolution than no distraction in some cases, incubation intervals are more beneficial for resolution in all types of problems.

The natural question arises as to why incubation intervals are more beneficial for resolution. It seems likely that initial fixation is occurring to some degree. An incubation interval is more beneficial in removing this fixation by removing the problem from visual sight. If the removal of fixation is indeed the reason that incubation is more beneficial than distraction, then this result and the resolution data for Helpful trials jointly support the Withdrawal of Attention hypothesis. Resolution occurs when fixation is removed as well as when incremental-like work is performed. The Withdrawal of Attention hypothesis predicts that resolution is optimal when both events occur. While more evidence is necessary before making strong conclusions regarding the mechanisms of incubation, the present study appears to support the basic elements of the Withdrawal of Attention hypothesis.

There are a couple limitations of the present study worth mentioning. The four experiments were designed to vary the attentional demands of the incubation/distraction task by using the Digit Monitoring Task with varied levels of difficulty. It is logical to assume that monitoring for patterns of five odd digits in-a-row would be more difficult than monitoring for patterns of two odd digits in-a-row because it requires more working memory. However, the rate of committing an error in the digit monitoring did not vary across the three conditions. It would not be correct to say that attention demands did not vary because the three conditions did have an effect on resolution rates. What is likely is that participants devoted the necessary amount of attention towards digit monitoring in order to perform adequately. Attentional resources are limited. During the incubation and distraction intervals, the Digit Monitoring Task and the resolution attempts on the RAT problem shared this pool of resources. Because resources were devoted to digit monitoring in each condition, the amount of cognitive resources available for incremental work on the RAT varied by condition. For example, the high condition required 80% of resources for digit monitoring (leaving 20% of resources available for incremental work), while the low condition required 40% of resources (leaving 60% available for incremental work). While this explanation is plausible, a limitation of this research is that what exactly occurred is unknown.

Another limitation is the issue of whether or not fixation occurred in the Blocking trials. Experiment 4 was designed to investigate the presence of a fixation effect through the use of counterbalancing trials as either Unrelated or Blocking. Although the solution rates were higher in the Unrelated trials, it was not significant, raising into question whether the Two-Word Phrase Task was effective in inducing fixation. The result was incongruent with the previous three experiments where the initial solution rates where greater for Unrelated trials than Blocking trials in every condition tested. Because different RAT problems were used for Unrelated and Blocking trials, it is not certain whether the difference in solution rates is due to fixation or due to the use of different problems. If fixation did not occur, then this would dampen the support for the Withdrawal of Attention hypothesis. However, due to the trend of greater initial solution rates for Unrelated trials than Blocking trials and that incubation intervals yielded greater resolution rates than distraction intervals, an assumption can be made that fixation occurred.

This study was also effective in demonstrating the effectiveness of trial-by-trial paradigms for investigating incubation effects. Past research has used paradigms in which the second attempts on trials did not occur until all the first attempts of trials occurred (Dodds *et al.*, 2003; Smith & Blankenship, 1989, 1991). Such paradigms introduced the possibility of extraneous effects during a trial's incubation intervals. Despite these studies demonstrating incubation effects, one cannot separate the beneficial effects of the incubation period from the effects of noise (i.e., Trial 5's first attempt providing an unintended helpful or blocking clue during Trial 1's incubation interval). It is hoped that with further refinement, this trial-by-trial design will allow further investigation of incubation and distraction's mechanisms. Incubation research is now starting to use online imaging. Experiments using *f*MRI have yielded evidence of the neurological basis of insight using RAT problems (Jung-Beeman *et al.*, 2004). Due to the nature of *f*MRI readings, this research would benefit greatly by implementing the trial-by-trial paradigm of the present experiment. A trial-by-trial paradigm would isolate when exactly incubation occurs, and allow for a more precise reading of the neural activity involved in incubation.

It would be also be beneficial to further investigate the mechanisms underlying incubation and distraction intervals using a non-neural imaging technique. Follow-up experiments to the present study should try to remove the floor effect, further investigate differences between medium and low distraction levels, and examine difference between incubation and distraction intervals on a subject-by-subject basis. One way to do this is to create an experiment using a within-subject design. Instead of manipulating attention demands between groups, trials could vary in the attention demands. Furthermore, some trials could involve incubation intervals while other contain distraction intervals. To raise resolution rates, a different priming task would be used.

The implications of such research can allow us to better understand the mechanisms of incubation and distraction. This could have applicable value for production in engineering (e.g., facilitate problem solving), instruction in the classroom (e.g., design lessons to take advantage of incubation), and creativity in design (e.g., increased efficiency and divergent thinking for think tanks/design teams). It is hoped that findings from the present study as well as future research will allow such applications to take place.

From the present study, it is not yet possible to apply the research to a real world setting. Doing so would require a complete picture of incubation. The present study did shed some light on the mechanisms of incubation and distraction intervals. When people are fixated, they can resolve problems best when they are moderately distracted by another task. This moderate degree of distraction allows for removal of fixation on an initial incorrect solution attempt, and allows work to be performed towards a solution. When a difficult problem is removed from sight, resolution will also benefit the most when the incubation task removes fixation and allows for incremental work. A summary of these findings can be found in Figure 5.

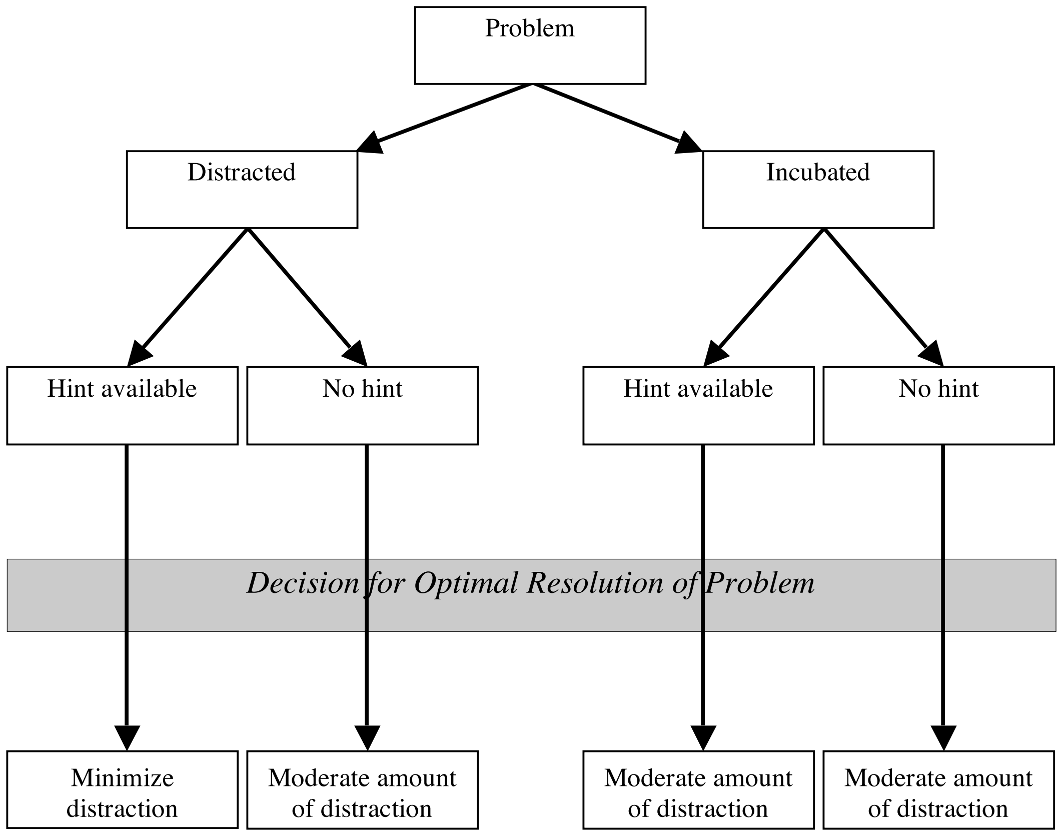


Figure 5. Decision Flow Chart for Problems That Are Not Initially Solved

REFERENCES

Bowers, K. S., Regehr, G., Balthazard, C., & Parker, K. (1990). Intuition in the context of discovery. *Cognitive Psychology, 22*(1), 72-110.

Browne, B. A., & Cruse, D. F. (1988). The incubation effect: Illusion or illumination? *Human Performance, 1*(3), 177-185.

Davidson, J. E. (1995). The suddenness of insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 125-155). Cambridge, MA: MIT Press.

Dodds, R. A., Ward, T. B., & Smith, S. M. (2003). A review of the experimental literature on incubation in problem solving and creativity. In M. A. Runco (Ed.), *Creativity research handbook* (Vol. 3). Cresskill, NJ: Hampton Press.

Dominowski, R. L., & Jenrick, R. (1972). Effects of hints and interpolated activity on solution of an insight problem. *Psychonomic Science, 26*(6), 335-338.

Estes, W.K. (1955). Statistical theory of spontaneous recovery and regression. *Psychological Review, 89*, 627-661.

Gall, M., & Mendelsohn, G. A. (1967). Effects of facilitating techniques and subject-experimenter interaction on creative problem solving. *Journal of Personality and Social Psychology, 5*(2), 211-216.

Glenberg, A.M. (1979). Component-levels theory of the effects of spacing of repetitions on recall. and recognition. *Memory & Cognition, 7*(2), 95-112.

Goldman, W. P., Wolters, N. C. W., & Winograd, E. (1992). A demonstration of incubation in anagram problem solving. *Bulletin of the Psychonomic Society, 30*(1), 36-38.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies, 12*(1), 3-11.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., et al. (2004). Neural activity when people solve verbal problems with insight. *PLoS Biology, 2*(4), 500-510.

Luchins, A., & Luchins, E. (1959). *Rigidity of behavior: A variational approach to the effect of einstellung*. Eugene: University of Oregon Books.

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220-232.

Murray, H. G., & Denny, J. P. (1969). Interaction of ability level and interpolated activity (opportunity for incubation) in human problem solving. *Psychological Reports, 24*, 271-276.

Olton, R. M. (1979). Experimental studies of incubation: Searching for the elusive. *Journal of Creative Behavior, 13*(1), 9-22.

Olton, R. M., & Johnson, D. M. (1976). Mechanisms of incubation in creative problem solving. *American Journal of Psychology, 89*(4), 617-630.

Patrick, A. S. (1986). The role of ability in creative incubation. *Personality & Individual Differences, 7*(2), 169-174.

Patrick, C. (1938). Scientific thought. *The Journal of Psychology, 5*, 55-83.

Peterson, C. (1974). Incubation effects in anagram solution. *Bulletin of the Psychonomic Society, 3*(1), 29-30.

Silveira, J. (1971). *Incubation: The effect of interruption timing and length on problem solution and quality of problem processing*. Unpublished doctoral dissertation, University of Oregon. Eugene, OR.

Smith, S. M. (1995). Getting into and out of mental ruts: A theory of fixation, incubation, and insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 229-250). Cambridge, MA: MIT Press.

Smith, S. M., & Blankenship, S. E. (1989). Incubation effects. *Bulletin of the Psychonomic Society, 27*(4), 311-314.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *American Journal of Psychology, 104*(1), 61-87.

Smith, S. M., Sifonis, C. M., Tindell, D. R., & Dodds, R. A. (1993). Incidental cues and incubation: Priming vs. Passive spreading activation. *Memory & Cognition, 21*(6), 837-845.

Smith, S. M., & Vela, E. (1991). Incubated reminiscence effects. *Memory & Cognition, 19*(2), 168-176.

Wallas, G. (1926). *The art of thought.* New York: Harcourt.

Weisberg, R. W., & Alba, J. W. (1981). An examination of the alleged role of "fixation" in the solution of several "insight" problems. *Journal of Experimental Psychology, 110*(2), 193-198.

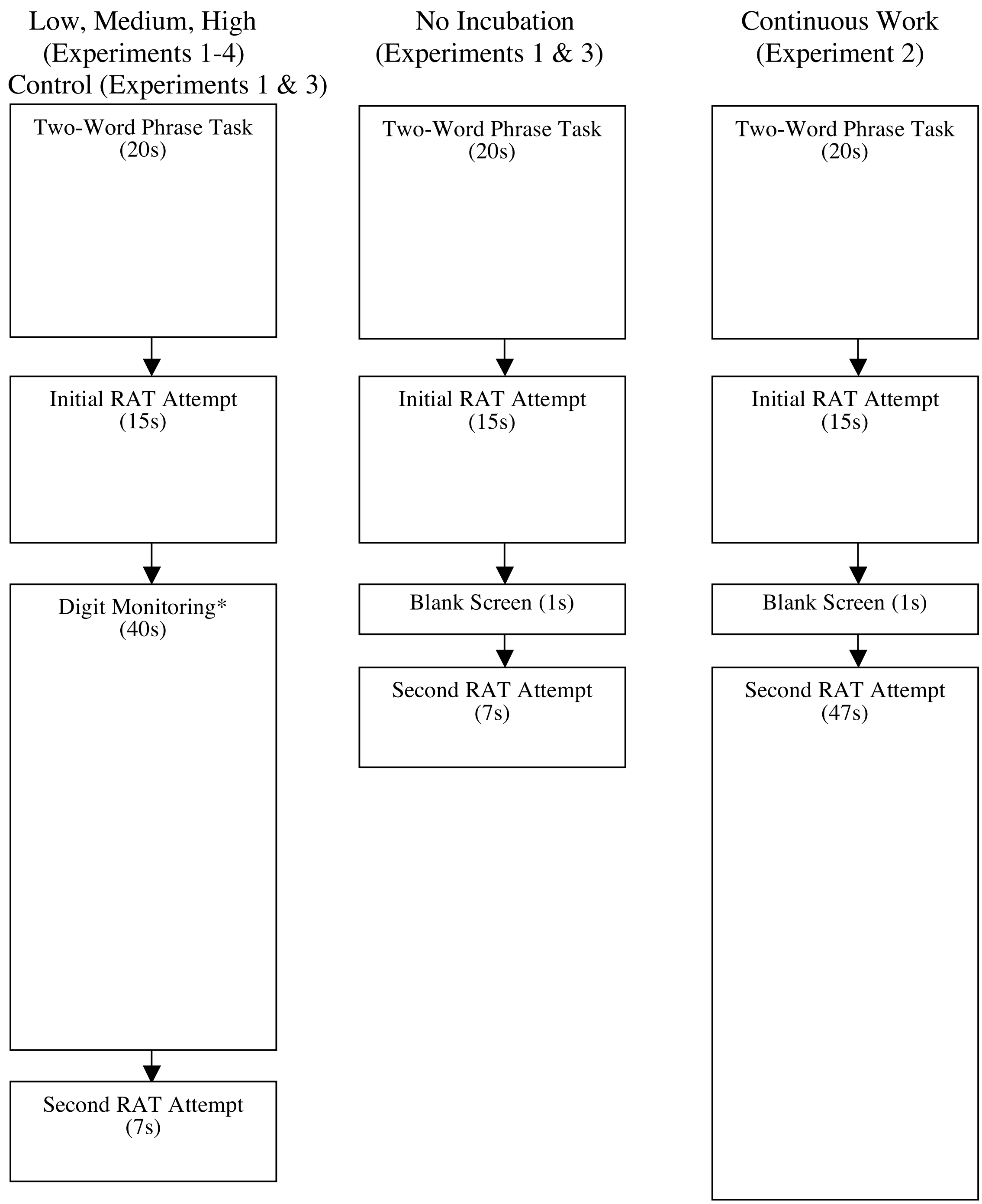
Wiley, J. (1998). Expertise as mental set: The effects of domain knowledge in creative problem solving. *Memory & Cognition, 26*(4), 716-730.

Woodworth, R. S., & Schlosberg, H. (1954). *Experimental psychology*. New York: Holt, Rinehart & Winston.

Yaniv, I., & Meyer, D. E. (1987). Activation and metacognition of inaccessible stored information: Potential bases for incubation effects in problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*(2), 187-205.

APPENDIX A

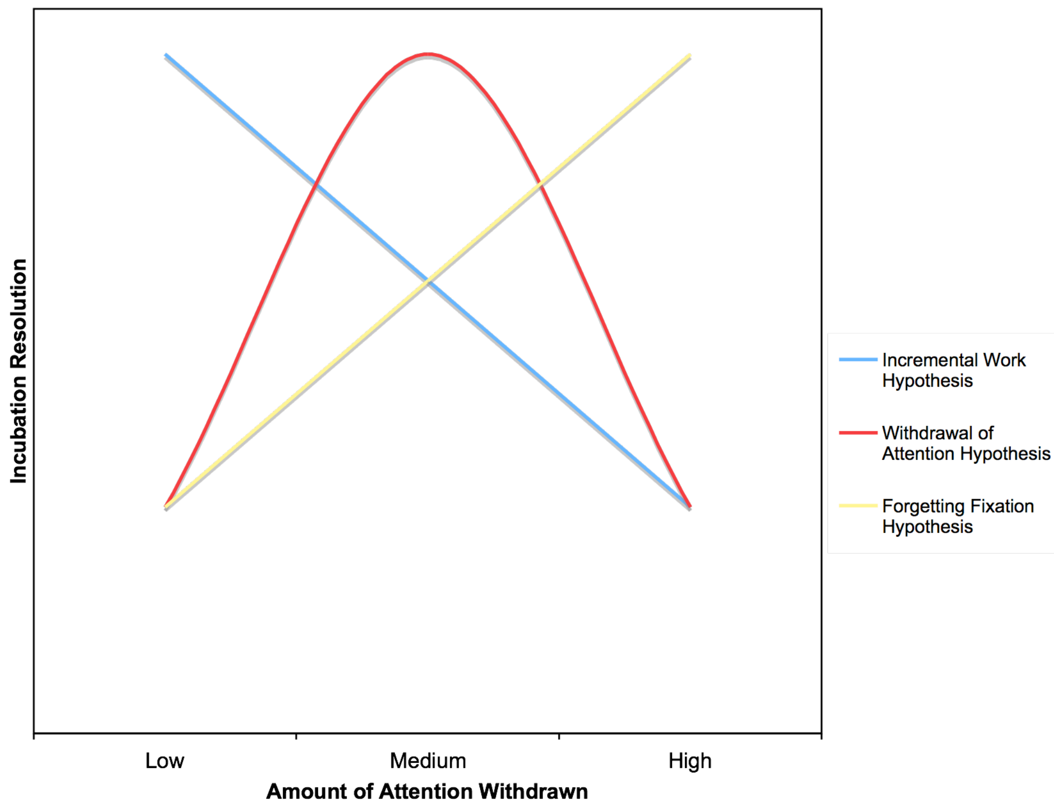
PARADIGM USED FOR CONDITIONS IN THE FOUR EXPERIMENTS



* RAT problem present in Experiments 1 and 2; RAT problem not present in Experiments 3 and 4

APPENDIX B

PREDICTED RESOLUTION RATES FOR THE THREE HYPOTHESES



APPENDIX C

RAT PROBLEMS USED IN THE PRESENT STUDY

RAT Problem			Solution	Blocker	Two Word Phrase Task		
Salad	Head	Goose	Egg	Lettuce	Lettuce	Head	Salad
Widow	Bite	Monkey	Spider		Bite	Monkey	Spider
Picture	Window	Door	Frame		Frame	Window	Picture
Top	Shoe	Car	Box	Horn	Top	Horn	Car
Worm	End	Shop	Book		Broken	Felt	Heart
Hot	Catcher	License	Dog	Plate	Plate	Hot	License
Arm	Coal	Stop	Pit	Rest	Stop	Rest	Arm
News	Plate	Clip	Paper		Traffic	Drug	Jam
Ship	Suit	Parking	Space	Jump	Suit	Jump	Ship
River	Note	Blood	Bank		Bank	Note	River
Sick	Swell	Mist	Sea		Sick	Sea	Mist
Light	Main	Sweeper	Street		Ball	Touch	Soft
Apple	House	Family	Tree	Green	Green	Apple	House
Manners	Round	Tennis	Table		Back	Ground	Pack
Storm	White	Ball	Snow	Cloud	Cloud	White	Storm
Falling	Movie	Dust	Star		Movie	Dust	Star
Water	Cube	Skate	Ice	Sugar	Sugar	Water	Cube
Electric	High	Easy	Chair	Wire	High	Electric	Wire
Goat	Pass	Range	Mountain		Hop	Door	Bell
Water	Tobacco	Stove	Pipe		Loud	Speaker	Mouth
Sandwich	Golf	Foot	Club		Foot	Club	Sandwich
Bed	Duster	Weight	Feather	Room	Weight	Bed	Room
Cat	Sleep	Board	Walk	Black	Cat	Black	Board

APPENDIX D

NON-SIGNIFICANT INTERACTIONS CALCULATED IN ANOVAS FROM EXPERIMENT 4

Table D1

Non-significant interactions from the 2(blocking vs. unrelated) X 2(primed vs. not primed) X 4(CB1, CB2, CB3, CB4) X 3(low, medium, high) mixed ANOVA was calculated using the proportions of RAT problems solved initially as the dependent variable.

Interaction	F-statistic
priming X incubation level	$F(2,48) = 0.87$, $MSE = .05$
priming X trial type	$F(1,48) = 1.67$, $MSE = .04$
priming X trial type X incubation level	$F(2,48) = 0.01$, $MSE = .04$
priming X incubation level X trial type X counterbalancing	$F(6,48) = 1.07$, $MSE = .04$
priming X incubation level X counterbalancing	$F(6,48) = 0.65$, $MSE = .05$
trial type X incubation level	$F(2,48) = 0.15$, $MSE = .04$
trial type X incubation level X counterbalancing	$F(6,48) = 1.12$, $MSE = .04$
incubation level X counterbalancing	$F(6,48) = 1.38$, $MSE = .06$

Table D2

Non-significant interactions from the 2(blocking vs. unrelated) X 2(primed vs. not primed) X 4(CB1, CB2, CB3, CB4) X 3(low, medium, high) mixed ANOVA was calculated using incubation resolution as the dependent variable.

Interaction	F-statistic
priming X incubation level	$F(2,46) = 1.49$, $MSE = .04$
priming X counterbalancing	$F(3,46) = 0.10$, $MSE = .04$
Priming X incubation level X counterbalancing	$F(3,46) = 1.21$, $MSE = .04$
priming X trial type	$F(1,46) = 0.01$, $MSE = .05$
priming X incubation level X trial type X counterbalancing	$F(6,46) = 0.25$, $MSE = .05$
priming X incubation level X counterbalancing	$F(3,46) = 0.03$, $MSE = .04$
trial type X incubation level	$F(2,46) = 0.83$, $MSE = .03$
trial type X counterbalancing	$F(3,46) = 0.61$, $MSE = .03$
trial type X incubation level X counterbalancing	$F(6,46) = 1.07$, $MSE = .03$
incubation level X counterbalancing	$F(6,46) = 0.46$, $MSE = .02$

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Conference Publications

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Yu, N.-Y., Yamauchi, T., & Kohn, N. (2005). The inductive potential of labeling: Beyond syntactic categories. 9th International Cognitive Linguistics Conference.

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